CHAPTER 15: THE SUPERHEATER

Superheated steam is saturated steam that has been "superheated".

Saturated steam, steam that is in contact with the water that produces it, both at the same temperature and pressure, in equilibrium, the steam may have moisture, but it cannot have a temperature higher than that of the water that produces it, see saturated steam tables.

If saturated steam is moist, to begin superheating it will first receive heat, evaporating the moisture or "droplets," maintaining the same temperature until it becomes "dry" saturated steam.

This "dry" saturated steam is then heated above its saturation temperature as it passes through a zone where it receives more heat, which does not increase its pressure but does increase its temperature.

For example:
steam at 10 kg/cm² (142 PSI) is saturated at a temperature of 183°C (361°F).

If this steam receives more heat by passing through a zone with a higher temperature, its temperature will rise above 183°C (361°F), but its **pressure will neither rise nor fall from 10 kg/cm² (142 PSI)** unless it is compressed or there is a pressure drop.

We can say that saturated steam can be wet or dry (without water droplets), while superheated steam is dry steam, and its behavior is similar to that of gases.

What is superheated steam used for?

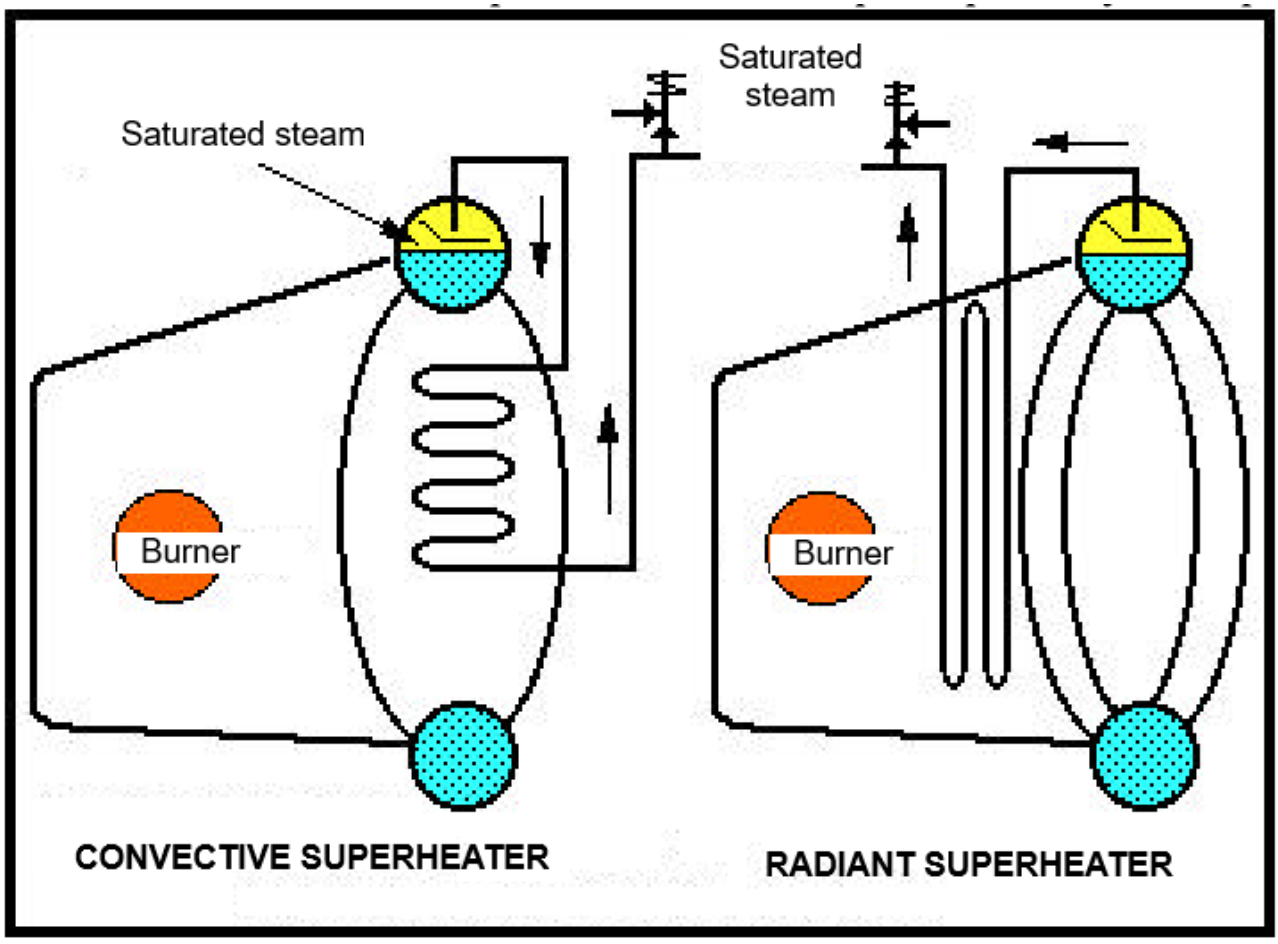
When it is necessary to operate a steam turbine, if saturated steam were used, droplets would form in the steam as it cools.

Steam Turbine Rotor Blades, SOURCE: wikipedia

At the speed at which the steam drives the turbine blades, these droplets would act like pellets, breaking the metal upon impact with the blades.

It is also used in some steam transport applications or steam engines to ensure that the steam arrives dry (without droplets or moisture).

Superheated steam is not ideal for heat transfer because it tends to behave like gases (which require a larger heat transfer surface, hence the finned design of gas or air heat exchangers). Tables are available for superheated steam, providing its characteristic values based on pressure and temperature.



INTEGRATED SUPERHEATERS

Superheaters are generally justified in power generation boilers (where turbines drive machines or electric generators, or power a ship's propulsion).

Therefore, they are generally installed in water-tube boilers because medium and high pressures are used, as they are not feasible in fire-tube boilers due to the pressure and large capacities required.

However, some fire-tube boilers may have a small superheater (usually in the smoke box) for minor steam superheating for transport or special use.

This superheating is around 15°C to 50°C (59°F to 122°F) and not much more, whereas in water-tube boilers the superheating can reach hundreds of degrees Celsius, even exceeding 300°C (572°F) in some cases.

In the case of fire-tube boilers, the superheaters are integral to the boiler (that is, they are always in the boiler's steam and flue gas circuits).

Their superheat is determined by the design, and the boiler operator has very little control over the superheat.

In water-tube boilers, the superheater can be integral, separate, or partially separate from the main combustion flow or influence.

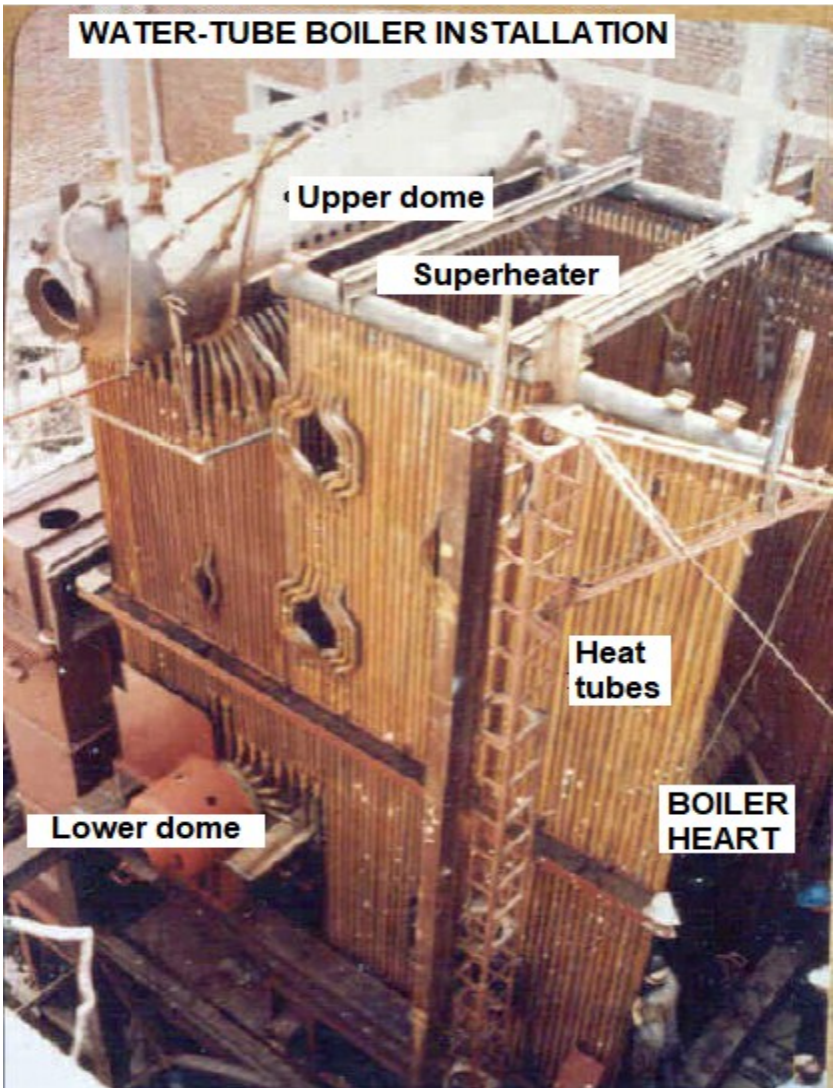
If the superheater is separate or partially separate, the temperature can be regulated by the operator, taking combustion into account. In the superheater area, there is a burner designed for this purpose, or baffles that direct the flue gas flow.

When the superheater is integral, the variation lies in its position relative to the boiler's combustion (that is, depending on its position, it will be a superheater influenced by direct exposure to combustion, "radiant," meaning exposed to the radiation of the main flame; or only influenced by the passage of gases, in which case it will have a screen of boiler tubes that protects it from combustion radiation, "convective," since it is protected from the radiant heat of the flame).

A superheater can have a mixed characteristic, meaning that without being entirely radiant, it has some exposure to flame radiation.

Excess air and the use of cold water feed tend to increase the superheating temperature, etc., all of which lower the boiler's efficiency.

In the integral superheater, the steam temperature can be regulated by injecting water (demineralized or pure condensate; never use water containing anything other than pure water) or by bypassing it to a tube cooler inside a water dome of the boiler itself.



What are the most significant problems with superheaters?

I believe we should discuss at least three, especially regarding integral superheaters:

The first is starting up a boiler with a superheater without "burning out the superheater," that is, without exceeding the temperature of the metal.

While superheaters up to relatively low temperatures (approximately 400°C - 752°F) are made of the same material as the boiler, when operating at higher temperatures they are made of more refractory materials (iron with elements such as chromium, nickel, molybdenum, etc., which are more resistant to high temperatures).

STARTING UP BOILERS WITH SUPERHEATER

All superheaters have the problem of startup, since at this stage the boiler gases (which are at a high temperature) and the fact that steam is not circulating inside the superheater (meaning the tubes are subjected to the temperature of the gases or the radiant flame), and also because at this start-up stage the steam has a low density (kg/m³), meaning that although there may be a volume flow, at this stage the mass flow or weight is not very high and the steam temperature can "spike" due to a lack of cooling mass.

It should be noted that these superheaters can also be divided into floodable superheaters (which can be filled with water for startup) and
non-floodable superheaters (which cannot be flooded for startup, making them more vulnerable to "burning out" at this stage).

Ideally, the boiler should be started with auxiliary steam circulation from another boiler, so as not to leave the boiler's heating stage dry.

In any case, the "start-up" or heating process must be very slow, venting steam to the atmosphere to maintain a cooling steam circulation, whether from auxiliary steam or steam generated within the boiler itself, with very close monitoring of the superheater temperature.

Then, the steam will be transferred to the consumption system, and the steam valve to the atmosphere will be closed in a coordinated manner.

If the superheater is floodable and there is no auxiliary steam, it is advisable to flood the superheater with demineralized water or pure condensate (never boiler water, since the evaporation of the salts will leave the superheater walls scaled with dry salts each time it is started).

But if the superheater is not floodable, greater care must be taken during the start-up (very gently), always venting steam to the atmosphere.

The superheater should NEVER be left without steam circulation while the boiler is lit or when high-temperature gases are present (as when shutting down a boiler with a large amount of refractory material).

As mentioned previously, the boiler's safety valves are regulated so that the superheater valve opens first (and generally has a significant steam release capacity to prevent overheating) and closes last.

This also applies when shutting down the boiler; never close the superheater steam valve before extinguishing the fires.

Even allow a slight vent to the atmosphere for a few minutes after extinguishing the fires to monitor the superheater metal temperature.

WATER CARRYOVER

The second point regarding the superheater is: under no circumstances should water carryover be allowed in the boiler.

Boiler **water carryover** contains salts that deposit in the superheater (and also affect the turbines), insulating the metal from the cooling effect caused by the passage of superheated steam.

This causes the metal's temperature to rise above what it can withstand, and the superheater "burns out."

Carryovers are generally due to: excessive momentary steam consumption in the industrial plant, pH issues, excess free soda, the presence of surfactant contaminants, high TDS (Total Dissolved Solids), or insoluble salts, etc.

One situation that can cause boiler water carryover is when there is a drop in boiler pressure (due to momentary excessive consumption, a combustion problem, etc.).

When the pressure drops, the specific volume of the steam increases dramatically (its density or specific weight decreases). In other words, the same weight of steam (its consumption in kg/hour) increases in volume.

For example, saturated steam at 40 kg/cm² (569 PSI) occupies 0.049 m³/kg. If the pressure drops to 30 kg/cm² (427 PSI), its volume increases to 0.066 m³/kg, a 34% increase.

This volume increase creates two unfavorable conditions that cause carryover: first, the boiler level rises (the steam decompresses within the water where it forms, increasing the volume of bubbles, like a carbonated beverage when it's opened); and second, the velocity of the steam at the interface between the steam and the water increases (which makes separation difficult and promotes entrainment).

These boiler water carryovers not only tend to scale the superheater, but also affect the steam turbines (the impact of water droplets on the turbine blades causes erosion and scaling that unbalances the turbine, causes vibrations/noise, and reduces turbine efficiency by affecting the nozzle passages and altering the surfaces of the turbine blades).

In the event of a significant pressure drop, stop the turbine!

The third point regarding the superheater is its maintenance when the boiler is out of service.

It must be maintained under the same conditions as the rest of the boiler: flooded with treated water to prevent oxygen corrosion, with a pH no lower than 10.5, and with a hydraulic seal to absorb the water's expansion due to ambient temperature variations and prevent air (oxygen) ingress.

Of course, there are other problems to consider in the superheater: as high-temperature gas-side corrosion.

The effect of vanadium contained in the fuel oil, ash erosion from burning coal or cellulose fuels, attack by some salts, especially potassium salts in biomass, etc.

And low-temperature corrosion when the boiler is out of service, generally caused by sulfur and ambient humidity (this is corrected with indirect heating).

The issue of chemical cleaning must also be considered.

When superheaters are specialized, acids that could damage these metals should not be used.

For example, hydrochloric acid, one of the most important chemical cleaning agents, especially due to its effectiveness and cost, damages high-temperature superheaters that contain chromium and nickel alloys.

C.W.T. (Carlos Walter Thomasset writting first version
of the STOKER BOILER HANDBOOK (“Pequeño Manual del Foguista”),
Apple Macintosh 128K computer,
first one sold in Uruguay by Martin Ponce de Leon to C.W.T. year 1984